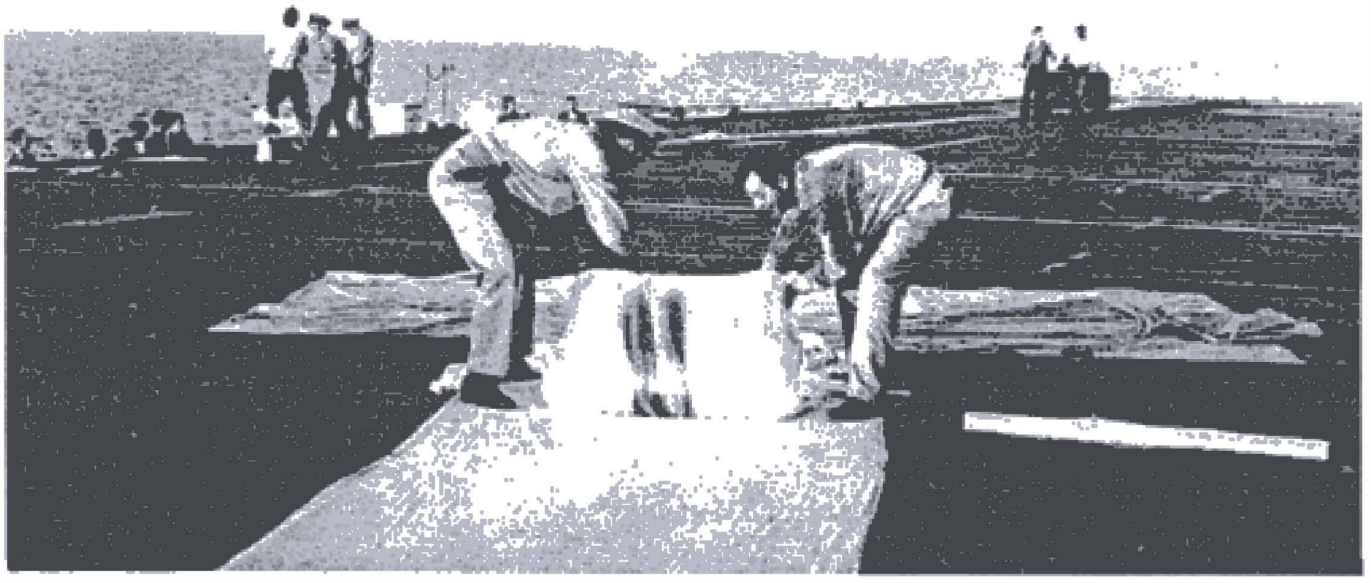

Cosmic Rays over the Caribbean

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During the first two weeks of November 1949, representatives of ONR, NRL, General Mills Inc., the Brookhaven National Laboratory, the University of Minnesota, University of Chicago, and New York University were taken aboard the USS PALAU to carry out the second series of Skyhook balloon flights in an area near the geomagnetic equator. With the cooperation of the ship's personnel, nine successful flights were made which should provide valuable information on high-altitude cosmic-ray events at low geomagnetic latitudes. The records obtained have been returned to the various laboratories for careful evaluation.

INTRODUCTION

Early in the present century, cosmic radiation was "discovered" or, more accurately, was identified as ionizing radiation of extra-terrestrial origin, as a result of experiments utilizing balloon-borne equipment. Ever since these early flights of Hess and Kolhörster in 1911-1914 to altitudes up to about 30,000 feet, cosmic ray physicists have laboriously worked their way higher and higher in an effort to eliminate the complicating effects of the blanket of air which enshrouds the earth.

Laboratories have been established on mountain tops up to 14,000 feet above sea level. B-29 "flying laboratories" have cruised for several hours at 40,000 feet. In 1935 a manned balloon rose to over 72,000 feet. Since World War II cosmic ray equipment has been carried over 100 miles aloft in rockets. However, rocket-borne equipment remains at high altitudes only for a few fleeting moments--far too short a time to amass reliable statistics on events of low probability. Airplanes, although extremely useful, are expensive to operate and are incapable of rising above more than approximately three fourths of the earth's atmospheric mass. Mountain-top laboratories, invaluable for accumulation of data over long periods, are still handicapped by the mass of air; almost

Fig. 2. Balloon inflation begins. The men are separating the folds in the delicate fabric.

two thirds of the total atmosphere still remains above them.

PREVIOUS SKYHOOK RESEARCH

In an effort to provide a reasonably satisfactory solution to these problems, development was begun towards a large aerostat, or free balloon, intended to carry appreciable loads of scientific equipment to the upper reaches of the atmosphere. During the past two years, under contract with the Office of Naval Research, the General Mills Aeronautical Laboratories of Minneapolis, Minnesota, have developed and produced a number of the huge "SKYHOOK" balloons. These tremendous cells, over 100 feet in height and 70 feet in diameter, made of 1/1000 inch thick polyethylene film and containing 226,000 cubic feet of gas when fully inflated, are capable of carrying payloads of well over 100 pounds to altitudes of approximately 100,000 feet above sea level, below which lies 99% of the earth's atmosphere--an upper region to which the incoming cosmic rays can penetrate with comparative ease. Because of the proximity of the General Mills Laboratories, most of the flights have been made from the vicinity of Camp Ripley at Little Falls, Minnesota, with valuable scientific results. An example of these results is the discovery that heavy nuclei, stripped of their orbital electrons and possessing energies of many billions of electron volts, exist as part of the primary cosmic radiation. However, in view of the fact that these flights usually involve observations of charged particles, cosmic ray investigators find it highly desirable to make comparable observations at varying geomagnetic latitudes in order to measure the effect of the earth's magnetic field upon the incoming charged radiation.

Shore-based expeditions to equatorial regions are complicated by numerous factors, not the least of which is the difficulty of recovering equipment dropped in foreign terrain hundreds of miles from the launching point. Arrangements were made, therefore, to launch four SKYHOOK balloons in the Caribbean area from the flight deck of the aircraft carrier USS SAIPAN.

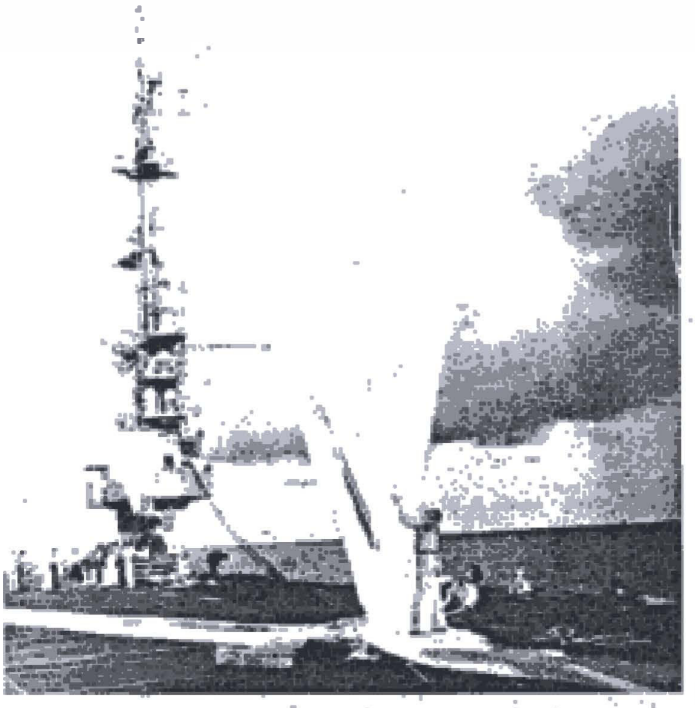

Fig. 3. The fully-inflated balloon ready for launching.

The results of these flights during the spring of 1949 proved so profitable that, during the following summer, plans were made for a much more extensive series of flights in the Caribbean from the USS PALAU, CVE 122, under the command of Captain T. O. Dahl. It was originally hoped that these experiments would be performed farther south, near the geomagnetic equator; however, due to the ready availability of patrol aircraft and excellent shore facilities, the vicinity of Cuba was chosen as an operating area.

PREPARATIONS FOR THE OPERATION

During the first week of November, 1949, representatives of the Office of Naval Research, General Mills, Inc., the Naval Research Laboratory, Brookhaven National Laboratory, the University of Minnesota, the University of Chicago, and New York University assembled, with their equipment, at the Patuxent Naval Air Station for transportation to Guantanamo Bay, Cuba. This transportation, involving fifteen people, a number of tons of delicate scientific equipment, and occupying most of the space in two R5D flights, was a major undertaking in itself and was carried off without incident by the Fleet Logistics Support Wing.

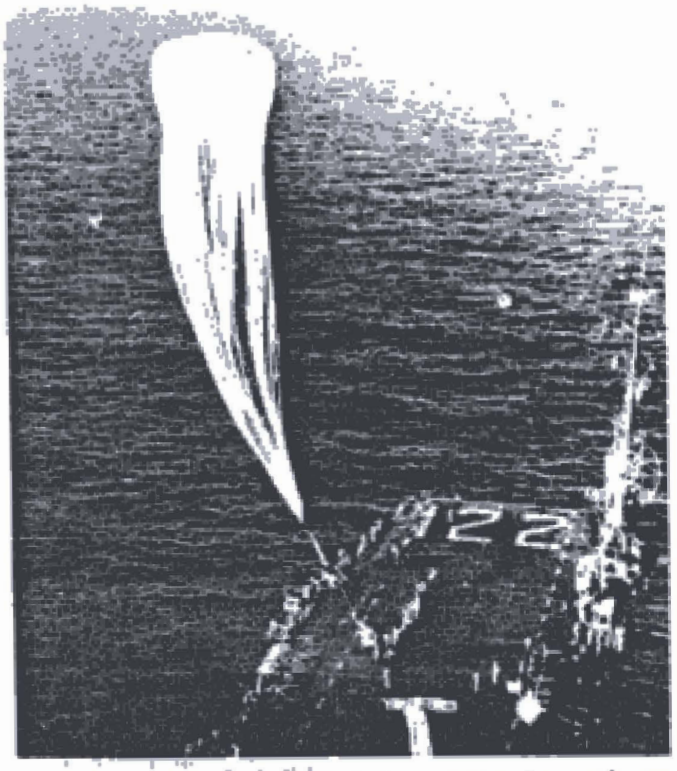

Fig. 4. The balloon is launched, carrying the cosmic-ray measuring equipment.

The last group of scientists arrived at the Naval Air Station at Guantanamo Bay on 7 November and the following two days were spent in last minute checking of equipment and in discussing the forthcoming operation with the officers of Utility Squadron TEN, who were to play a vital part in its success by providing patrol aircraft for tracking the balloons from the air and a helicopter for temporary duty aboard the PALAU.

On 10 November the scientific group boarded the PALAU and began preparations for the first two flights, which were scheduled for the morning of 12 November.

Equipment was being readied for a variety of experiments. A flight for Professor E. P. Ney, of the University of Minnesota, was planned to investigate meson showers and to measure both the east-west effect and the abundance of light (atomic number less than 10) nuclei in the so-called "heavy particle" component of the cosmic radiation, by means of an automatic counter-controlled cloud chamber and directionally oriented packages of nuclear emulsions. Mr. B. Stiller, of the Naval Research Laboratory, desired to measure the absorption in lead and carbon of star-producing radiation and the heavy "stripped" nuclei, utilizing photographic emulsions. Similarly, by the use of emulsions, Mr. S. E. Golian, of the Brookhaven National Laboratory, planned to study the latitude effect and absorption in air and carbon of star-producing radiation, measure the east-west effect in heavy nuclei, and secure data at a comparatively low altitude (60-80,000 ft.) on the air absorption of

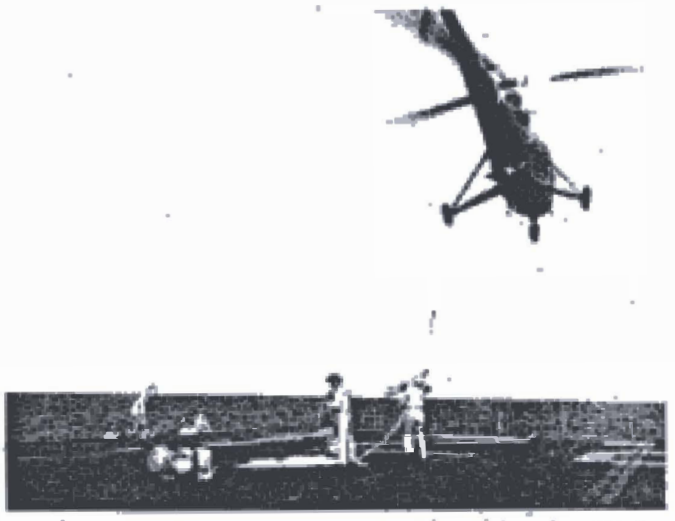

Fig. 5. A helicopter returns the "load" to the flight deck.

primary protons. By means of a Geiger counter "telescope" and photographic plates with carbon and paraffin absorbers, Mr. M. L. Vidale, of the University of Chicago, was to examine the phenomenon of multiple meson production and the multiplication of the "hard" component in lead.

Dr. M. H. Shamos, of New York University, had designed a photographically recording counter telescope to determine the east-west effect for protons in the primary radiation. W. P. Staker, also of New York University, utilized a standard telemetering arrangement to relay information on high and intermediate altitude neutron intensities obtained by an array of proportional counters. Finally, further data was to be obtained on neutron intensities by flying several packets of photographic plates provided by Dr. J. Simpson of the University of Chicago, who did not personally participate in the actual operation.

DESCRIPTION OF THE EXPERIMENT

The PALAU, accompanied by the USS FRASER, DM 24, which had been directed to assist in the operation, proceeded southward through the Jamaica Channel toward the first launching point at approximately 17° N, 75° W. Less than one and one half days remained until the first launching, and a strenuous effort was being made to get the scientific equipment ready, train the participating ship's personnel and organize an operating procedure.

The air-conditioned forward ready room, convenient to both the flight and hangar decks and equipped with adequate communication facilities to all parts of the ship, was turned over to the scientific personnel for laboratory use. Liaison was established with the FRASER and with Utility Squadron TEN regarding anticipated tracking and recovery problems. In the ship's

Command Operation Center, a number of officers and men were able to combine radar tracking of the balloons with normal underway watch duty. In addition, 34 of the ship's company were set up in three crews with the following responsibilities:

Balloon Crew: 1 Chief Petty Officer and 8 men to assist in laying out the ground cloth and the launching platform, rigging load lines and rolling out of balloons and to provide general assistance during inflation and launching.

Helium Crew: 1 Chief Petty Officer and 8 men to rig helium cylinders and manifold for inflation, regulate flow of gas, check cylinder pressures, and inflate of small balloons.

Tracking Crew: 2 teams of 8 men each to record course, speed and altitude of balloon flights.

The proposed launching schedule was made firm from 12 to 18 hours in advance of estimated launching time; on the night prior to launching, the load line, consisting of parachutes, radar reflectors, flotation spheres and scientific equipment, was arranged on the hangar deck.

Reveille was at approximately 0300 for the Balloon Crew, 0400 for the Helium Crew, and between 0430 and 0500 for the Tracking Crew, including COC personnel. Approximately two hours before launching time, the ship was conned into a low wind condition, at which time the balloon was rolled out on the ground cloth and the load line was brought up from the hangar deck, stretched out along the flight deck and attached to the balloon. When all was in order, the ship was conned for zero wind conditions, whereupon the balloon was inflated with helium, and last-minute scientific equipment was attached to the load line. In twenty minutes, the flight was ready for launching. By reference to several small meteorological balloons secured to the forward part of the flight deck and floating at levels of 100, 200, and 300 feet, the ship was then conned to provide a relative wind of four to five knots from about 150° relative, which insured the balloon and load clearing the ship's island and superstructure. The actual launching operation was under the direction of Mr. C. B. Moore, of General Mills, Inc., and Lt. F. A. Nelson.

Flight 1, carrying NRL's nuclear emulsions, was successfully launched at 0559 on 12 November, and Flight 2 for NYU at 0644. Since this second flight was equipped with telemetering equipment and was not to be recovered, tracking and recovery efforts were concentrated on the first balloon. It was believed (later established) that, after a breaking-in period for the personnel, two balloons could successfully be launched, tracked, and recovered each day.

In order to allow the accurate plotting of time-altitude data and to insure recovery of the scientific equipment, without which all but one flight would be worthless, a somewhat elaborate tracking system was established under the direction of LTJG M. L. Lewis. The tracking organization operated in three groups: Visual, Radar, and Chaser.

The Visual Group

The Visual Group was composed of four observers, three using mounted high power 20-120mm binoculars (two on the after bridge, one on the flight deck), and one observer on a theodolite. This group obtained relative bearings and elevation angles, while telemetering receivers acquired pressure data (each balloon on a different frequency). Stationed in Air Plot, adjacent to COC, was a "computer-recorder" man who received and converted pressure to altitude, and relative to true bearings. By use of a graph, he resolved altitude and elevation angle into range to the point directly beneath the balloon (nadir). From visual sources, the "computer-recorder" relayed to the Dead Reckoning Tracker the bearing and distance to the balloon. A graph man gave timing "marks" every five minutes to the optical trackers, DRT, and telemetering personnel to ensure synchronization between the observation of optical angles, ship's position and pressure-altitude data. He also kept graphs of the balloon's altitude versus time, and of the wind direction and velocity versus altitude during the flight.

From the "computer-recorder," the DRT received true bearing and distance to the balloon nadir and recorded this on the mark received from the graph man. Latitude and longitude of the launch, release and "splash" were indicated on this track. All stations in the Visual Group were linked together with the cross-connected JL and IJG sound powered telephone circuits.

The Radar Group

The Radar Group was made up of three men, one on the SP radar, one at the "recorder and slide rule" station, and one as the Dead Reckoning Tracker (same station as for the Visual Group). The SP radar operator, who furnished the recorder-slide rule man with true bearing, slant range and elevation angle, was able to track the balloons only when the elevation angle was 30° or less, due to the limited angle of elevation of the radar antenna.

The recorder-slide rule man resolved the SP radar range and elevation angle into altitude and distance to the nadir, and in turn transmitted true range and bearing of the balloon to the DRT, the third station in the group.

The radar tracking group utilized the 21 and 23 JS sound-powered circuits. It is to be noted that the radar and visual tracking groups used separate S/P nets due to the quantity of

SUMMARY OF FLIGHTS						
FLIGHT NO.	INSTITUTION	LAUNCHING TIME/DATE	FLIGHT DURATION MINUTES	PAYLOAD (POUNDS)	ALTITUDE REACHED (FEET)	REMARKS
1	Naval Research Laboratory	0558/12	578	161.9	96,000	Part of load lost during helicopter recovery
2	New York Univ.	0644/12	--	191.5	89,000	Telemeter. Recovery not required, so no release timer
3	Univ. of Minnesota	0614/13	91	167.5	84,500	Balloon burst. Equipment recovered and flown on Flight 9
4	Brookhaven Nat. Laboratory	0717/13	--	133.5	96,000	Timer failed to release load
5	Univ. of Chicago	0602/14	574	192.75	80,000	Experimental type intermediate altitude balloon
6	Univ. of Chicago	0540/15	526	159	91,000	
7	Brookhaven Nat. Laboratory	0607/16	527	148	93,000	
8	New York Univ.	0712/16	--	168	--	Balloon fouled in launching. Gear undamaged, flown on Flight 10
9	Univ. of Minnesota	0606/17	505	182.5	93,000	
10	New York Univ.	0657/17	511	153	92,000	
11	Univ. of Chicago and New York Univ.	0615/18	491	149	95,500	
12	Composite Flight	0715/18	495	168.5	90,000	

information being transmitted at each 5 minute "mark."

The Chaser Group consisted of a PBY5A, the crew of which followed the balloon visually and/or by tuning the radio direction finder to the balloon beacon signal. The escorting destroyer can also be considered a part of this group. Her movements were generally directed toward one of the two balloons by the PALAU COC. Occasionally the destroyer had the only contact with the flight, in which case she reported azimuth and elevation which, with her radar position, was sufficient to maintain the track.

Based on the wind data obtained during the ascent and the estimated rate of fall of the parachute-borne equipment, a resultant wind effect was computed for each release. With this and the observed high level winds the "splash" area was determined with a fairly high degree of accuracy. As a result of cloud cover, operational limitations of the ships, equipment failures, and dual flights, one or more of the tracking systems would often fail. However, with the three available, visual, radar and chasers, one method always could be actively employed to maintain a continuous track.

A typical curve of the "Skyhook" flight is shown below. Flight 12, flown for Brookhaven, NRL, and the University of Minnesota, rose at the rate of 1000 ft/min to 89,000 ft. The flight lasted for eight hours.

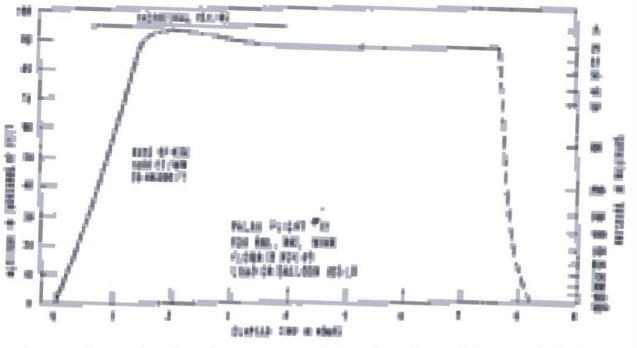

Fig. 6. Typical curve of Skyhook balloon flight.

Most of the balloons were launched in the vicinity of 16° 30" North and 74° 30" West, in order to provide the minimum sea room of 100 miles from land in all directions. It was planned to complete all launchings by 0700 each morning. The PBY which was used for visual tracking from the air had an endurance of eleven hours, and in order to have it on the station at the time

of load release and descent, a 0930 rendezvous was established each day with the belief that the balloon could be kept in sight from the PALAU for 2-1/2 hours after launching. Each balloon carried a beacon transmitting a radio signal between 1606 and 1746 kilocycles which was received by the PALAU and by the tracking PBY's direction finders. The final load release was scheduled so that the load would hit the water not later than approximately 1530, which left 2 hours for recovery and return before dark. In most cases the PBY was able to follow the descending load to the water visually and to indicate his position to the helicopter, which was launched in advance of the "splash," retrieved the load from the water, and returned it either to the PALAU or to the deck of the FRASER. The destroyer proved of great value in retrieving loads dropped from flights which had outrun the PALAU during the day, these loads being transferred by line to the PALAU at a later time.

Over a period of seven days, twelve launchings were attempted and eleven were completely successful. As a result of an unfortunate wind shift, Flight 8 fouled in the island structure upon launching and was cut away after retrieving the load, which was flown successfully on Flight 10. Balloon 3, carrying a 167 pound payload was launched without difficulty, but burst at an altitude of 84,300 ft. due to an excessive rate of rise; but the equipment was recovered immediately by helicopter and flown successfully on Flight 9. The release timer failed on Brookhaven's Flight 4, and the load was lost, but satisfactory data was obtained by flying duplicate items on several subsequent flights which were not loaded to capacity. A brief summary of the flights is presented in the accompanying table.

FUTURE ANALYSES

Following an operation such as this, a tremendous amount of study is necessary to properly analyze and evaluate the scientific results. As an example, more than a year may be required to scan and tabulate the photographic emulsions exposed on these flights. For this reason, the foregoing account has been, of necessity, largely an operational report, one which should indicate the extent to which the Navy, by the use of unique facilities, can contribute to the fundamental research effort of American scientists.